State of CERES

Norman G. Loeb
NASA Langley Research Center, Hampton, VA

CERES Science Team Meeting, May 16-18, 2017
NASA LaRC, Hampton, VA

CERES Meeting

Review status of CERES Instruments and Data Products:

- Status of CERES
- CERES Terra, Aqua, S-NPP SW/LW/TOTAL Channel Calibration Update
- CERES FM6 and RBI Update
- MODIS & VIIRS Cloud Algorithm & Validation Status
- ADM, SOFA, SARB and TISA Working Group Reports
- EBAF-TOA & EBAF-SFC Edition 4 Updates
- FLASHFLUX Update
- Data Management Team Update: Terra/Aqua/S-NPP
- Atmospheric Sciences Data Center (ASDC) Update
- CERES Communication Activities

CERES Team Leads

- Principal Investigator: Norman Loeb
- Project Scientist: Kory Priestley

CERES Working Groups:

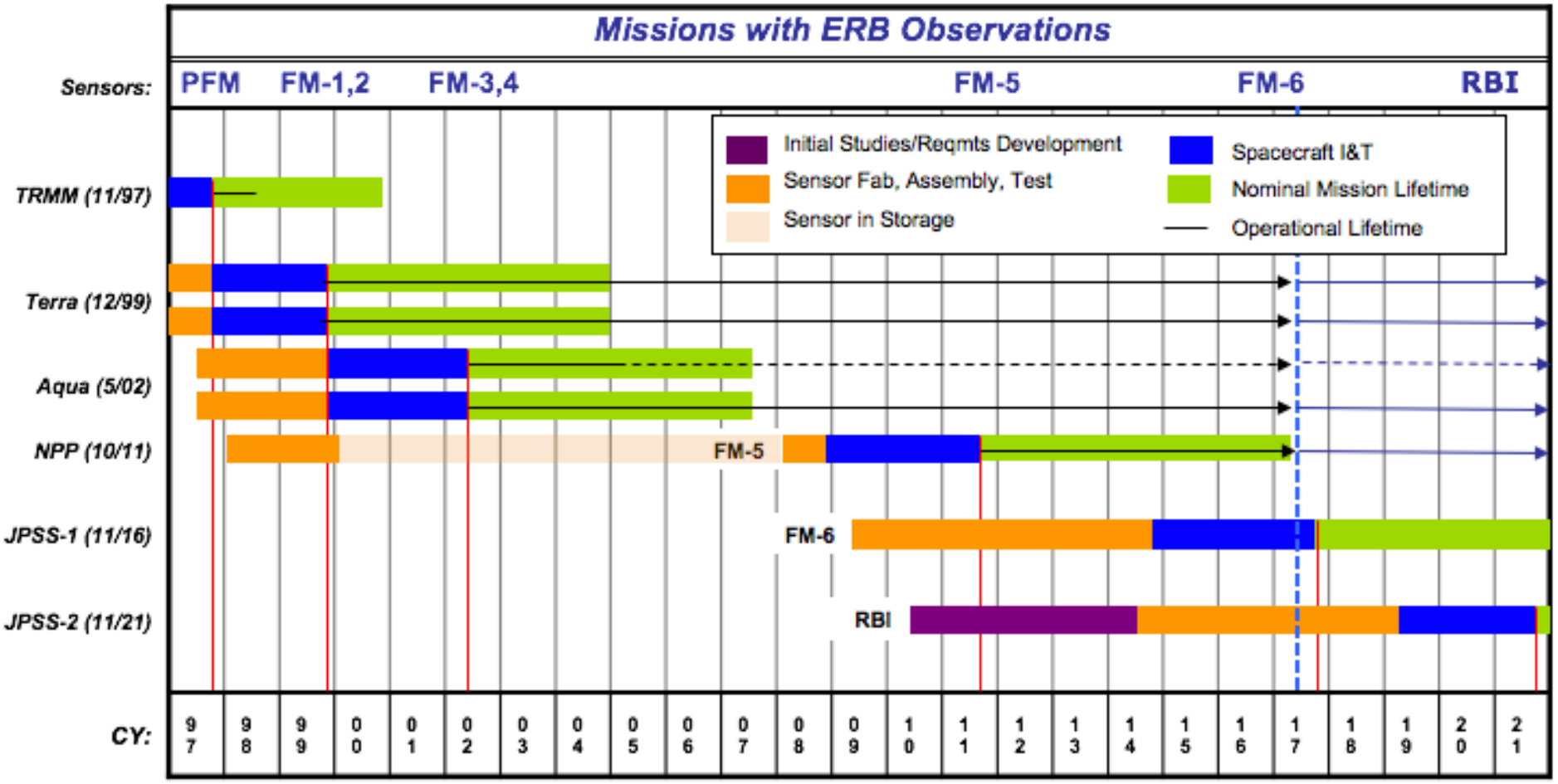
- Instrument: Kory Priestley
- Clouds: Bill Smith Jr.
- Inversion: Wenying Su
- SOFA: David Kratz
- SARB: Seiji Kato
- TISA: David Doelling
- ERBElike: Takmeng Wong
- FLASHFlux: Paul Stackhouse & David Kratz
- Data Management: Jonathan Gleason & Katie Moore
- ASDC: John Kusterer

Happy Retirement Pat!

Now you work for Bill!

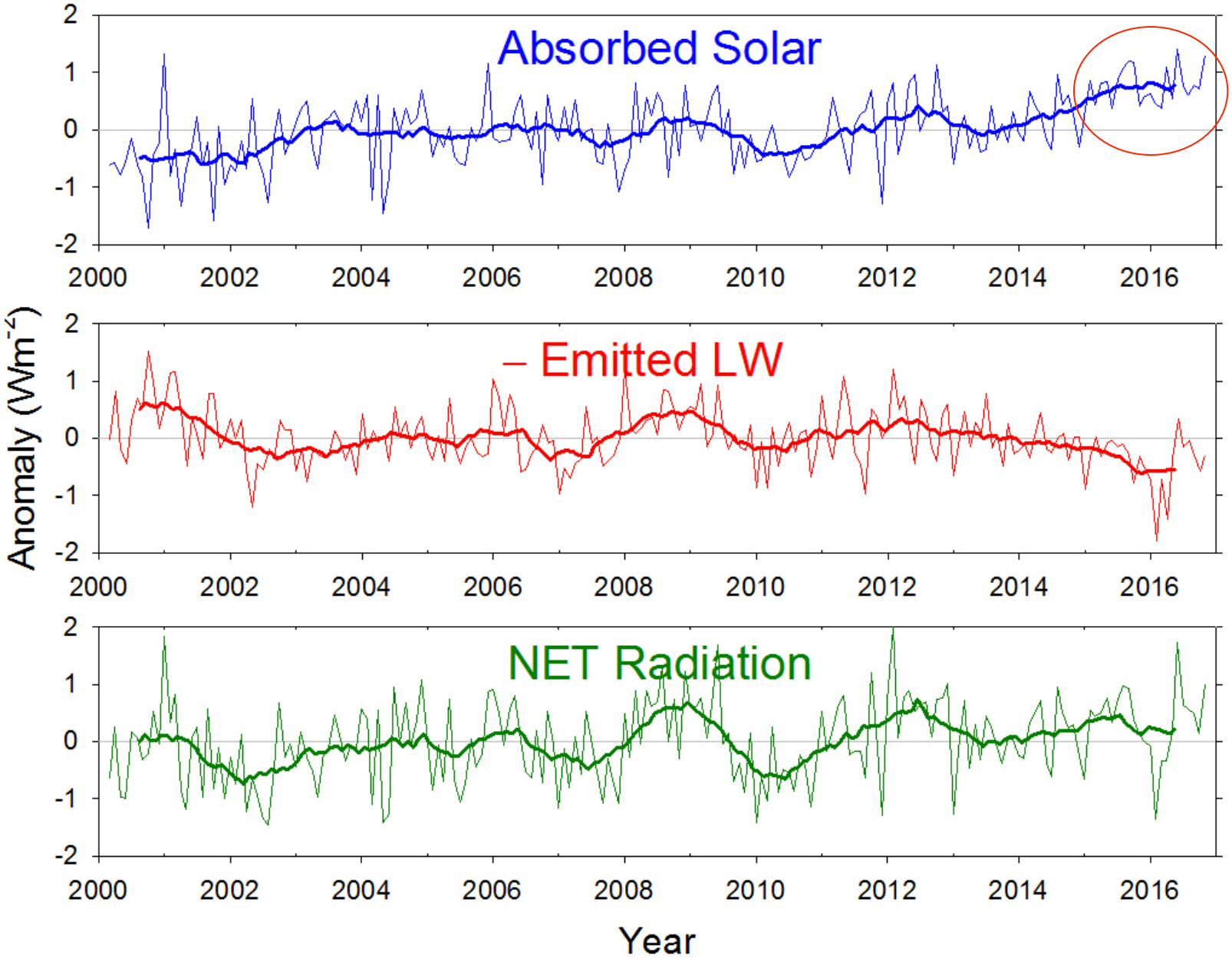
Go easy on him, Bill.

CERES & RBI Flight Schedules

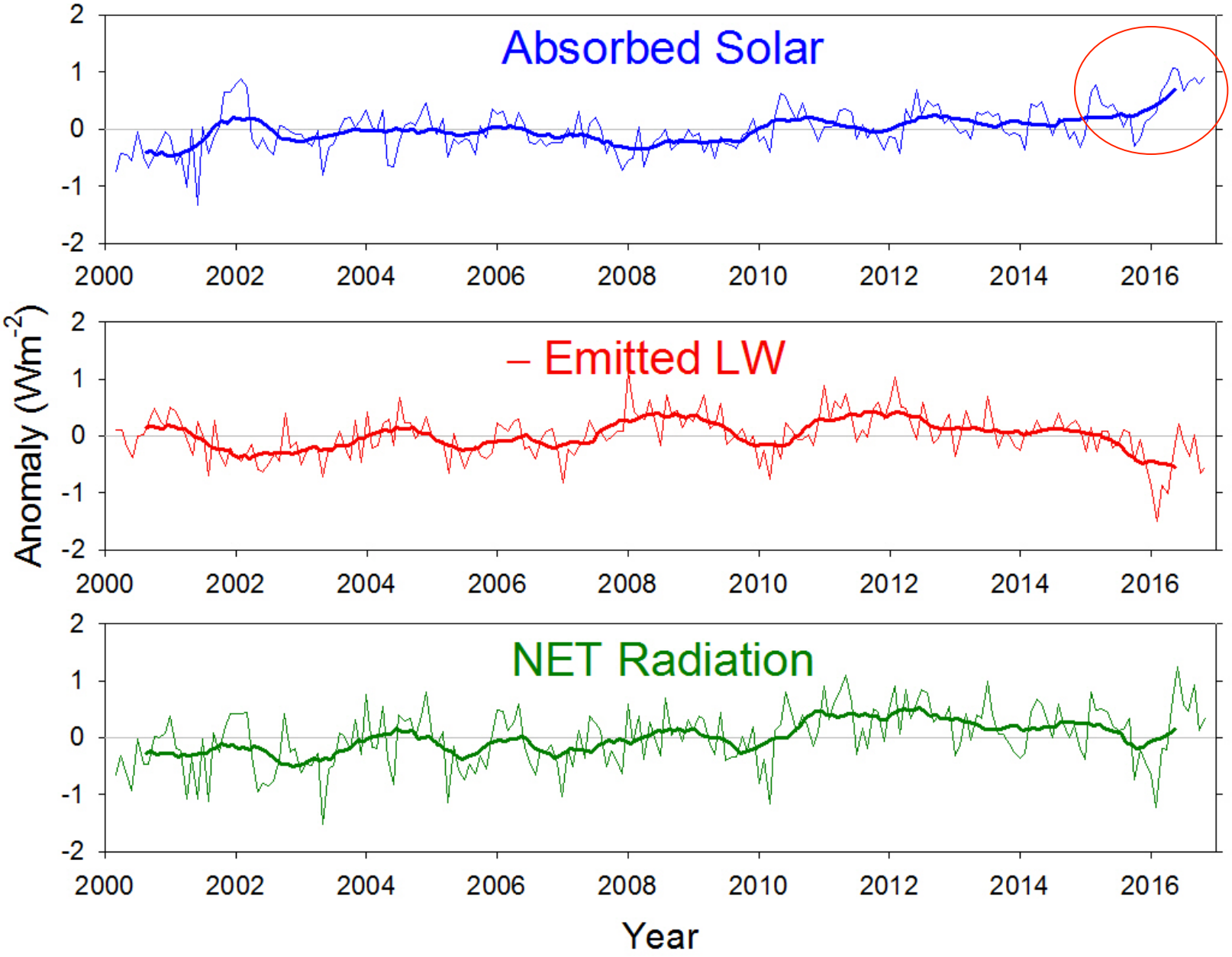


- Currently, 5 CERES instruments fly on 3 satellites: Terra (L1999), Aqua (L2002) and S-NPP (L2011).
- CERES FM6 will fly on JPSS-1 (Sept 21, 2017). The CERES follow-on instrument (Radiation Budget Instrument, or RBI) will fly on JPSS-2 in FY21 (4th Qtr).

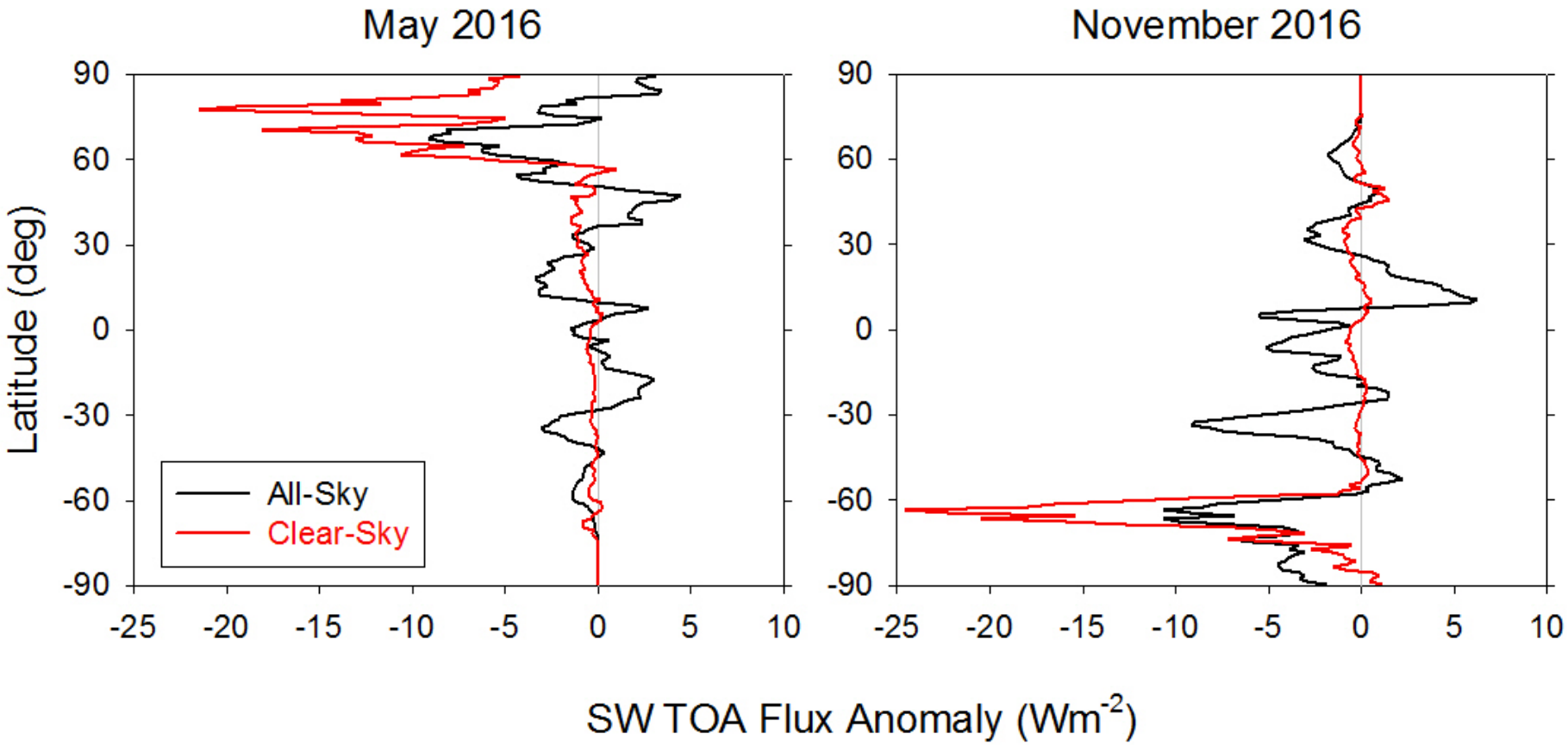
Global TOA **All-Sky** Radiation Anomalies
(CERES_EBAF_Ed4.0; 03/2000 – 11/2016)



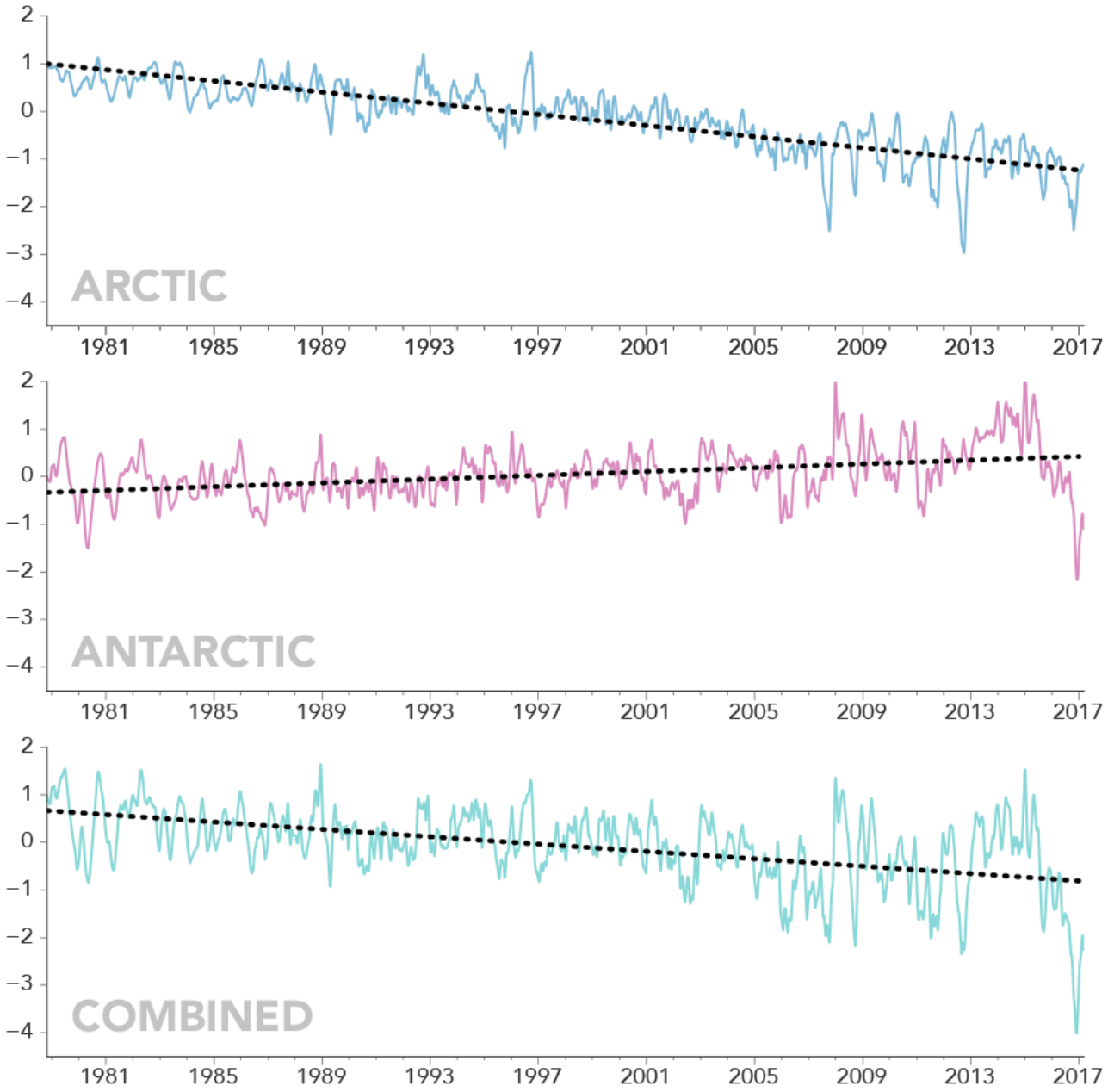
Global TOA **Clear-Sky** Radiation Anomalies
(CERES_EBAF_Ed4.0; 03/2000 – 11/2016)



Zonal Mean SW TOA Flux Anomaly

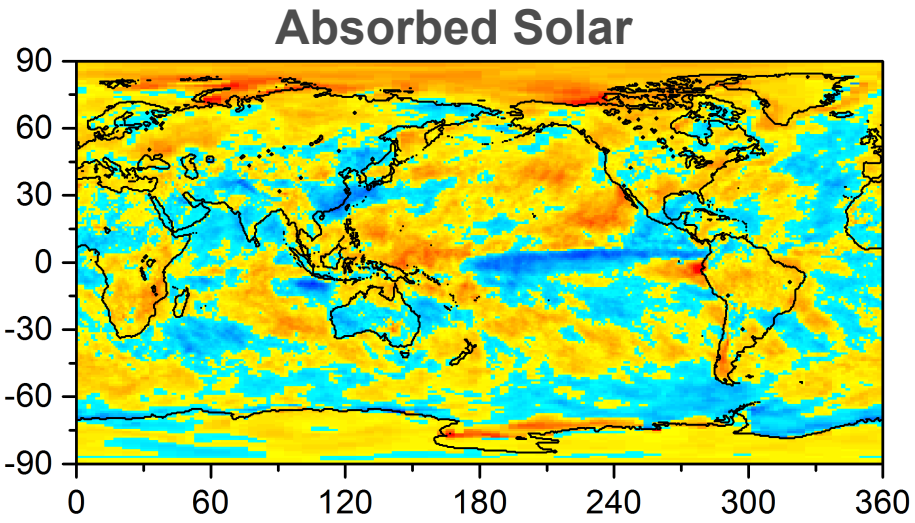


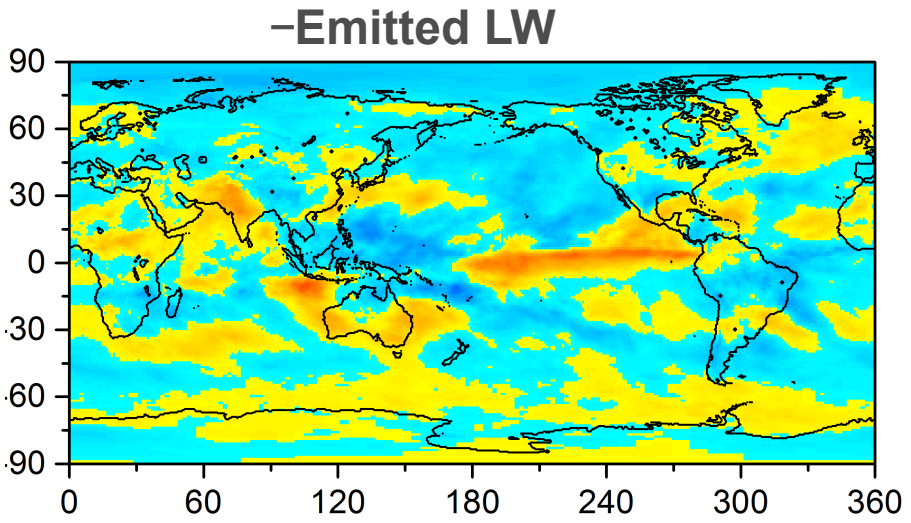
Deviation in Sea Ice Extent (x 1 million km^2)

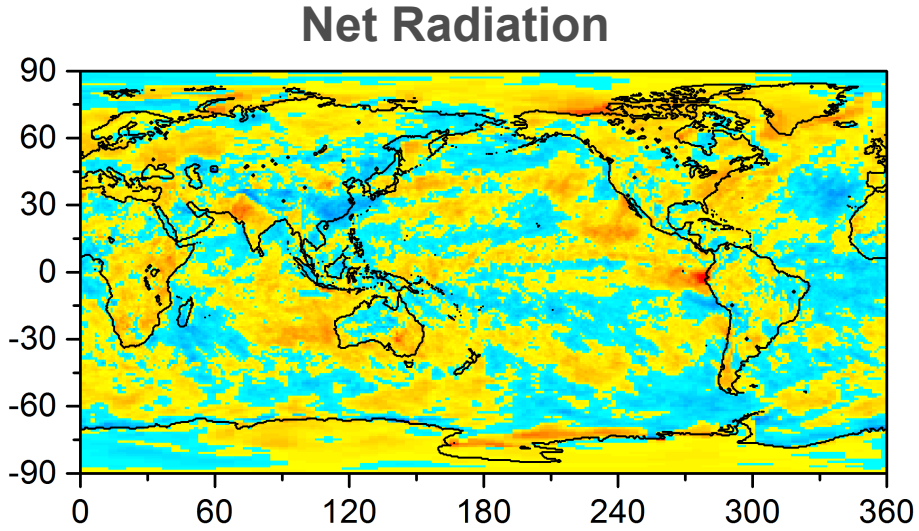


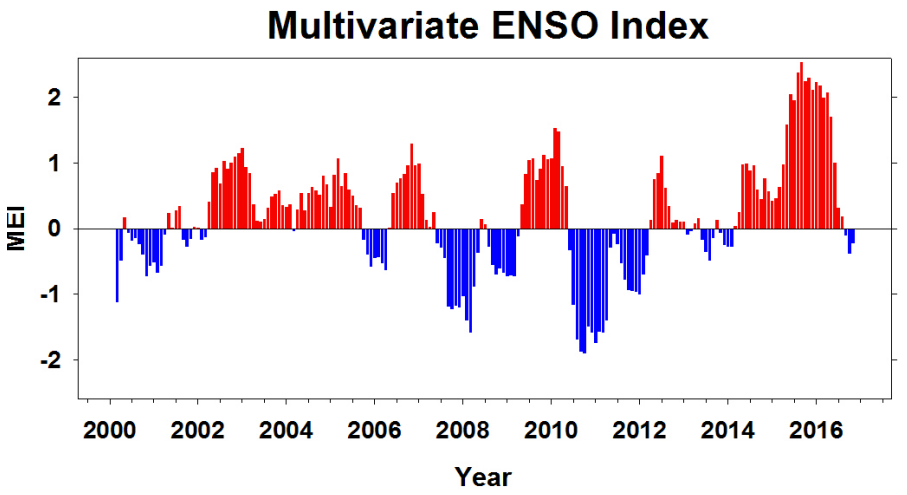
Source: NASA Earth Observatory

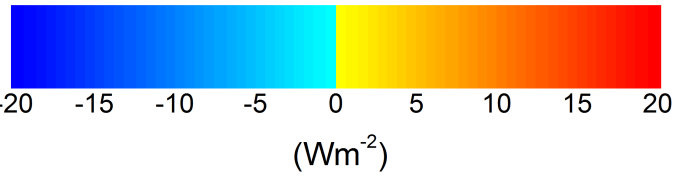
TOA Radiation Changes (March 2000 – November 2016)











Terra Lunar Deep Space Calibration (LDSC) Maneuver

- A DSC maneuver is an accelerated 240 degree pitch-over (360 relative to local horizon) during S/C night that provides observations of the cold background of deep space and an option for a lunar viewing.
- Two previous DSC maneuvers were executed in 2003:
  - March 26 maneuver was a deep space calibration (DSC).
  - April 14 maneuver was both deep space and a lunar calibration (LDSC).
- A LDSC provides the Terra instrument teams observations that can be compared against the LDSC in 2003.
  - Can be used to verify calibration changes from onboard calibration sources over the lifetime of the mission.
  - **A LDSC maneuver is scheduled for August 5, 2017.**

Terra Extended Mission Options

- A-Train Mission Operations Working Group (MOWG) unanimously approved a new exit plan that reduces the constellation exit from a 19-km lowering to 4-km.
- The change provides Terra with additional fuel that could be used to maintain the current MLT and altitude until fall 2020.
- This would increase the time before orbital reentry to 50 years after end of mission. Current requirement is 25 years.
- However, reentry requirements were enacted after Terra launch.
- Orbital debris risk posed by a Terra extended mission is very low.
- Various exit plans were considered by the Terra Project.
- Conclusion: Terra will maintain current MLT & altitude as long as possible.

Terra - 2017 Earth Science Division Senior Review

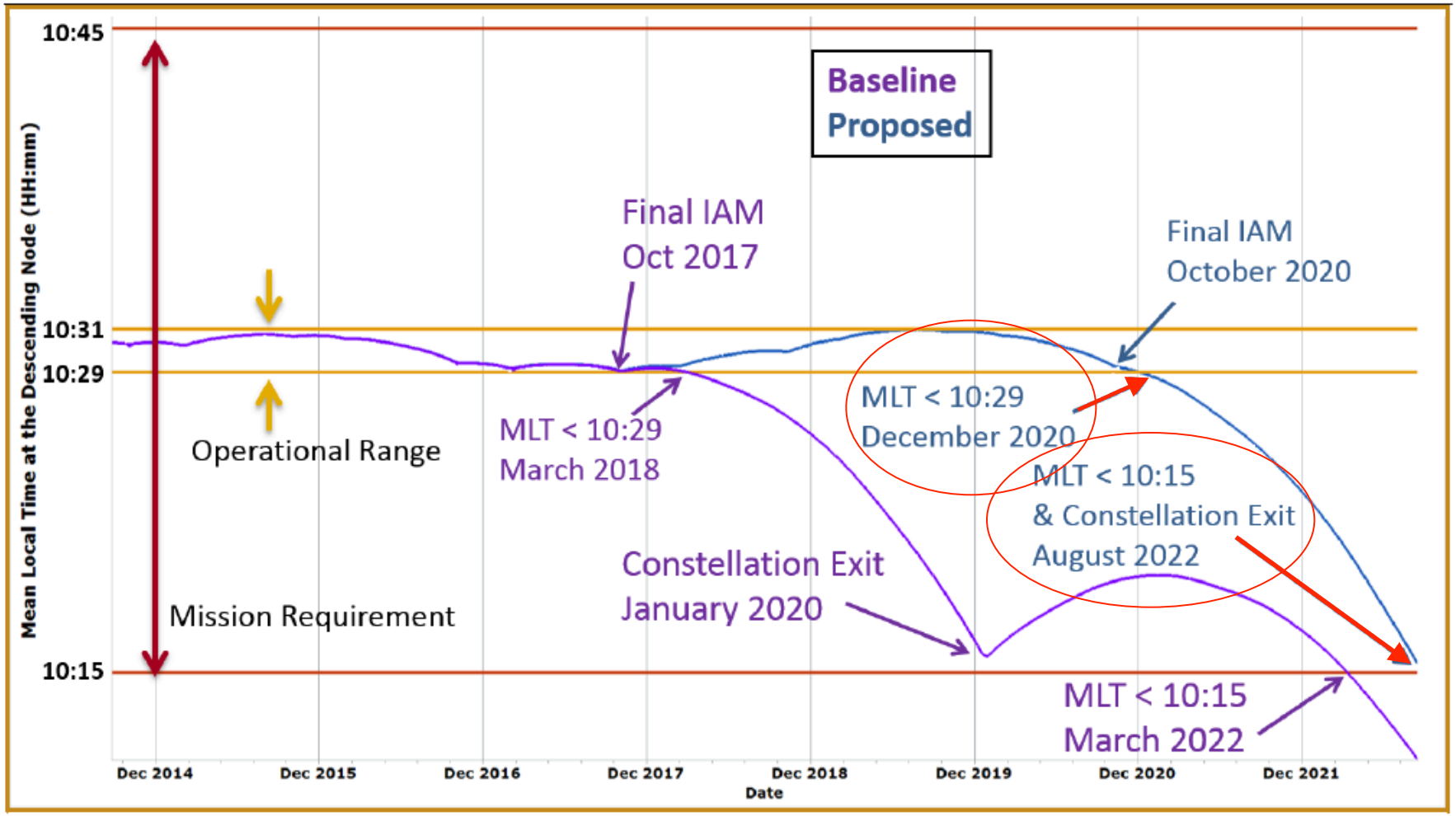


Figure F.4-2: Terra MLT following baseline constellation exit vs. proposed exit

End of Mission: 2026

Aqua Mission Life Expectancy & Planned Orbital Changes

- Maintain orbit altitude and MLT through March 2022, and continue to operate for three additional years.
- Orbit will drift to an MLT later in the day. The end of mission: 2025.

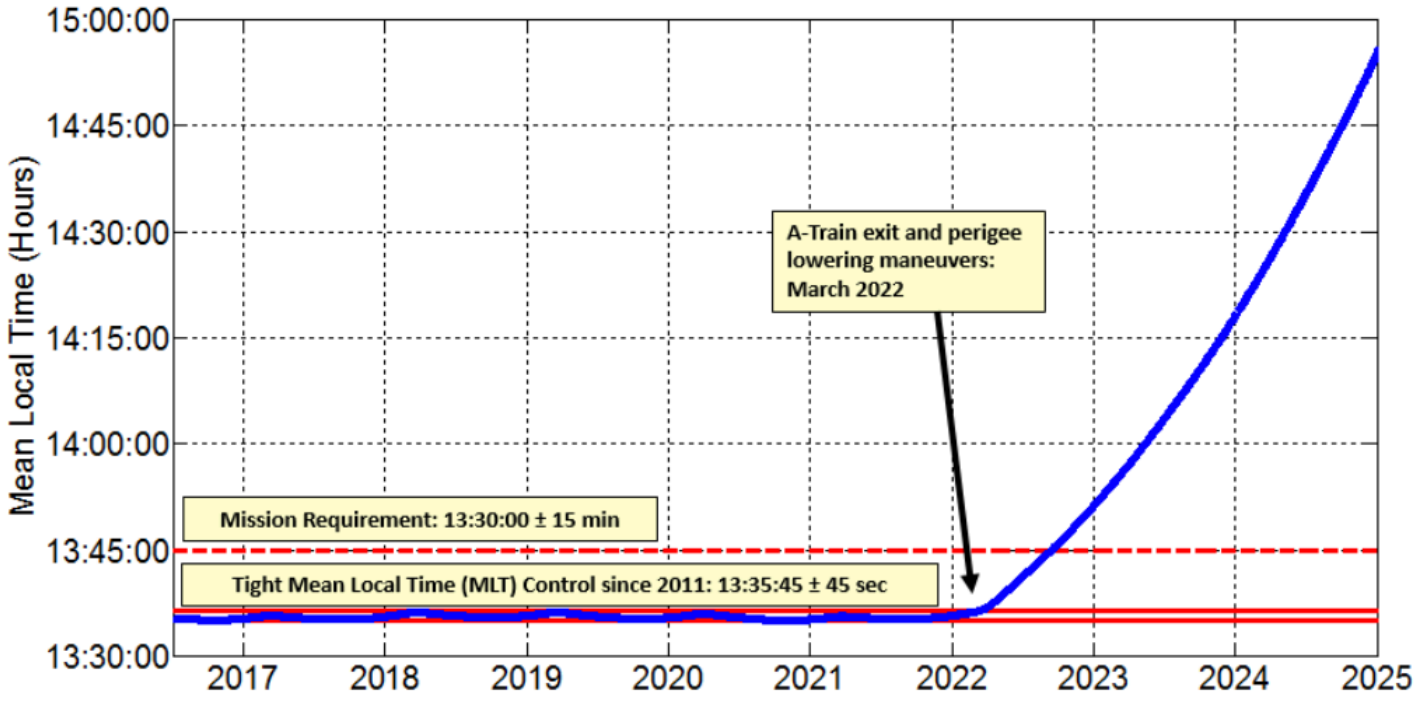
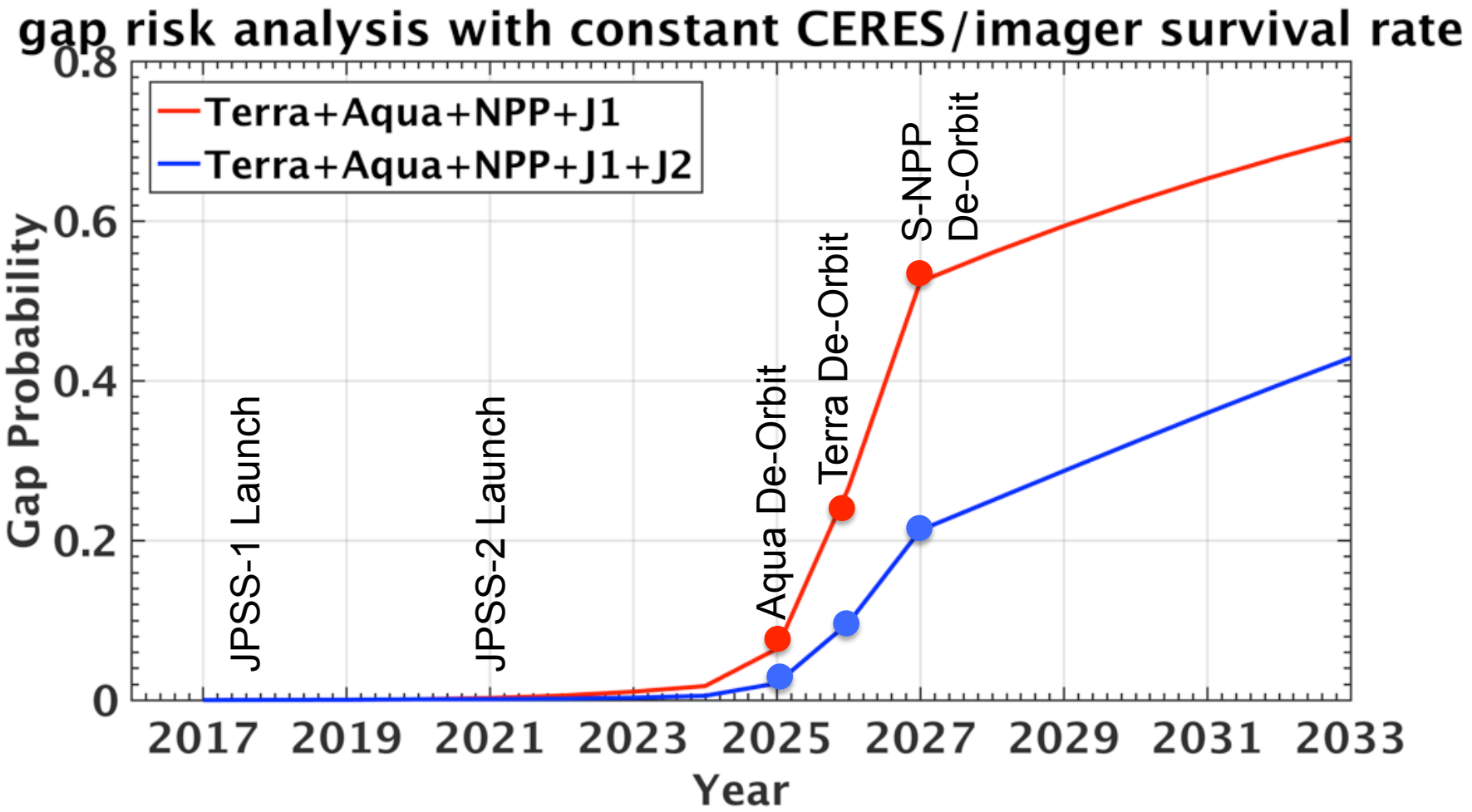


Figure E.7.1. Aqua's predicted Mean Local Time (MLT) of the ascending node crossing as the satellite passes from south to north over the equator, assuming an A-Train exit and perigee lowering in March 2022.



- Constant CERES, imager & spacecraft survival rates are assumed.
- Assume fuel is the only limiting factor for de-orbit date.
  - Assume 15-year missions for S-NPP, JPSS-1 & JPSS-2.
- Since simultaneous nadir overlap between S-NPP and JPSS-1 is very limited, we need significant overlap period between Aqua and JPSS-1 in order to intercalibrate S-NPP and JPSS-1.

CERES Reviews

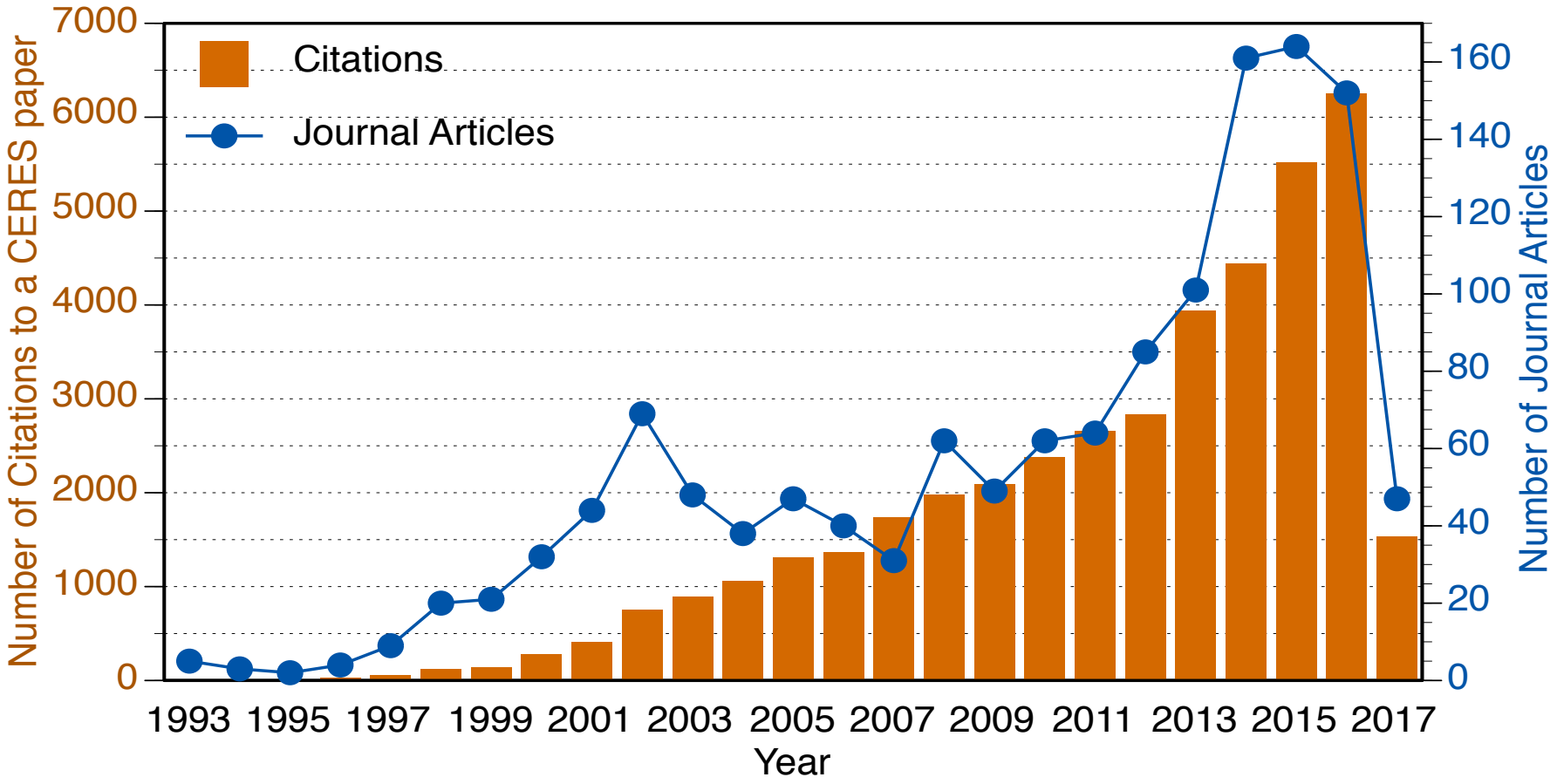
1) Earth Radiation Budget Science PPBE Review (date TBD).

2) Earth Radiation Budget Science Team Review (May 30)

3) Terra and Aqua Senior Reviews
- Proposals were submitted in early March.
- Panel reviews were were held on May 10.

4) S-NPP End of Prime Mission Review (date TBD).

CERES Journal Publications and Citation Counts
(For Papers Between 1993-2017; Updated April 24, 2017)



- Total number of peer-reviewed journal articles: 1,360
- Total number of citations to CERES papers: 41,799

(Compiled by Anne Wilber & Dave Kratz)

Number of Unique Users by CERES Data Product (through April 30, 2017)

Level	Product	2010	2011	2012	2013	2014	2015	2016	2017
1b	BDS	11	9	14	19	14	11	13	7
2	SSF	84	77	138	223	247	253	278	158
	FLASH_SSF	25	8	15	23	30	61	41	26
	C3M	31	32	33	37	28	55	54	15
	ES8	22	20	18	31	16	21	15	9
	SSF-MISR	9	4	2	5	4	2	1	
3, 3b	EBAF-TOA	72	160	346	484	579	580	540	144
	EBAF-Surface			147	289	375	424	464	192
	SYN1deg	70	139	188	331	375	431	483	241
	SSF1deg	130	182	156	215	237	212	276	129
	ISCCP-D2like	17	12	37	57	41	40	47	50
	ES4	59	36	11	27	19	13	12	9
	ES9	21	12	5	13	9	5	5	3
	FLASH_TISA	17	18	20	17	15	15	36	31

CERES Terra and Aqua Edition 4 – Status

- Instrument gains and SRFs: Delivered
  - Improvement to Aqua SW part of TOT SRF.

- CERES Clouds code: Delivered.
  - Increased cloud fraction (more consistent with CALIPSO).
  - Decreased cloud optical depth (more thin clouds).
  - Significant improvements to polar cloud mask.

- Inversion (ADMs and SOFA) code: Delivered.

•2nd generation CERES ADMs; Improved parameterized surface fluxes.

- SARB and TISA code: Delivered.
  - Use of 5-channel 1-hourly GEO cloud retrievals.
  - Consistent reanalysis and MODIS calibration throughout.
  - SYN1deg to be released 1-hourly, 3-hourly, daily and monthly.
  - Consistent non-GEO and GEO TISA products (all GMT).
  - Improved to Fu-Liou RT code and ancillary inputs (e.g., Ed4 clouds +overlap, surface albedo, MATCH aerosols).

  - EBAF-TOA (Released)
  - EBAF-SFC (Anticipated release May 24, 2017)

CERES Terra and Aqua Data Product Availability

Data Product	Level	Ed2.8	Ed3.0	Ed4.0
BDS	1	-	01/2017	01/2017
SSF	2	-	01/2017	01/2017
SSF1deg	3	-	12/2016	12/2016
SYN1deg	3	-	10/2016	10/2016 (to be released)
CldTypHist	3	-	01/2017	11/2016 (to be released)
EBAF-TOA	3b	01/2017	-	11/2016
EBAF-SFC	3b	08/2016	-	02/2016 (to be released May 24)

Note: 03/2017 will be last data month of Edition 3.0 and EBAF Ed2.8 production.

Edition1 Product Availability

Product	Platform	Processed through	Current	Publically Available
BDS	S-NPP	12/2016	Yes	Yes
SSF	S-NPP	12/2016	Yes	Yes
SSF1deg-Hour	S-NPP	11/2016	Yes	Yes
SSF1deg-Day/Month	S-NPP	11/2016	Yes	No
SYN1deg	Merged		08/2017	No

SSF1deg-Day/Month products being reviewed for public release.
SYN1deg will start in summer.

Towards a Seamless TOA & SFC ERB CDR

1) Current Status (EBAF-TOA & EBAF-SFC):

- Terra-only (03/2000-06/2002); Terra+Aqua (07/2002-Present).
- Terra & Aqua both fly CERES & MODIS instruments and consistent cloud and ADM algorithms run on both (Edition 4.0).
- CERES Terra and Aqua were placed on the same radiometric scale.
- Ed 4.0 CERES cloud algorithm uses MODIS water vapor and 13.3-14.2 μm bands (mask).
- ADMs consistent with MODIS clouds were generated separately for Terra and Aqua.

2) Strategy for Other Sensors (FM5, FM6, RBI)

- TISA codes have already been adapted to handle either Terra, Aqua, and SNPP inputs.
- S-NPP, JPSS-1 and JPSS-2 fly VIIRS imager and CERES or RBI.
- VIIRS imager does not have water vapor and 13.3-14.2 μm bands like MODIS.
- S-NPP has been in crosstrack mode since 2011
  - No S-NPP ADMs produced yet
  - S-NPP has not been placed on same radiometric scale as Terra & Aqua.

➢ Adding CERES S-NPP in 2011 to existing Ed 4.0 Terra+Aqua CDR would introduce a discontinuity in the existing CDR.

Towards a Seamless TOA & SFC ERB CDR

- Our plan is to generate an initial 5-year Terra+S-NPP product and assess what is needed to make it consistent with Terra+Aqua.
  - Place FM5/S-NPP on same radiometric scale as Terra & Aqua.
  - Place FM5/S-NPP in RAP mode to enable new ADMs for S-NPP after FM6/ JPSS-1 launches and has been checked out.
  - Consider whether cloud algorithm for CERES CDR needs to drop use of water vapor and 13.3-14.2 μm bands on MODIS to be consistent with VIIRS or supplement VIIRS with CrIS, which has the WV and 13.3-14.2 μm bands.
- Should Aqua fail: continue record with Terra+S-NPP.
- Should Terra fail: options are:
  - Apply algorithms for Aqua-only diurnal correction similar to those used during the Terra-only period (03/2000-06/2002).
  - Generate a record using only afternoon CERES instruments.
  - Rely on improved quality of 3rd generation of geostationary imagers to help reduce uncertainties due to loss of Terra.
- For each new CERES or RBI instrument, routinely produce the following:
  - BDS (Level 1b) -> SSF (Level 2) -> SSF1deg (Level 3).
    - ➢ Enables direct comparison between data records from individual satellites.

Plans for Improved Synoptic Clouds & Radiation with MODIS-Like Geostationary Imagers

- Once the contiguous constellation of 2nd generation 11-channel Meteosat and 3rd generation 16-channel GOES/Himawari geostationary (GEO) imagers are operational in 2019, we will use all available channels from GEO and MODIS & VIIRS to produce a Terra+Aqua+S-NPP+GEO hourly SYN1deg-hourly product for process/diurnal cycle studies.

- This will not have the same restrictions as the CERES CDR, which requires homogeneous record.
  - Remove any restrictions on imager channels (e.g., water vapor and 13.3-14.2 μm bands).
    - ➢ Improved cloud properties and surface fluxes.

- Will use the same code structure as is currently being used. Main improvement will be in the inputs (e.g., GEO imagers, MODIS/VIIRS channels, etc.).

- Benefits of a CERES Terra+Aqua+SNPP SYN1deg data product.
  - Reduces impact of any missing data in Aqua record.
  - Reduced TOA flux uncertainty through anisotropic factor weighting of Aqua and SNPP fluxes.

COVE

- DOE turned Chesapeake Light Tower (CLT) over to GSA for excess; GSA put CLT up for auction during spring 2015. Private new owners purchased CLT.
- We met the new owners. They were uncertain about how they would use the platform.
- We agreed to rent space on CLT to continue BSRN and AERONET operations.
- However, CLT did not pass NASA Safety inspection, so we cannot resume operations until new owners make needed repairs.
- All NASA equipment was removed from CLT.
- A 2nd BSRN instrument suite is operating at CAPABLE.
- A refurbished MPLNET instrument is expected to be operational at CAPABLE in June 2017.

Upcoming Conferences & Meetings of Interest

Gordon Research Conference: Radiation & Climate
- July 16-21, Bates College, ME.

Fall 2017 CERES Science Team Meeting
- September 26-28, NASA GSFC, Greenbelt, MD.

American Geophysical Union
- December 11-15, 2017, New Orleans, LA.

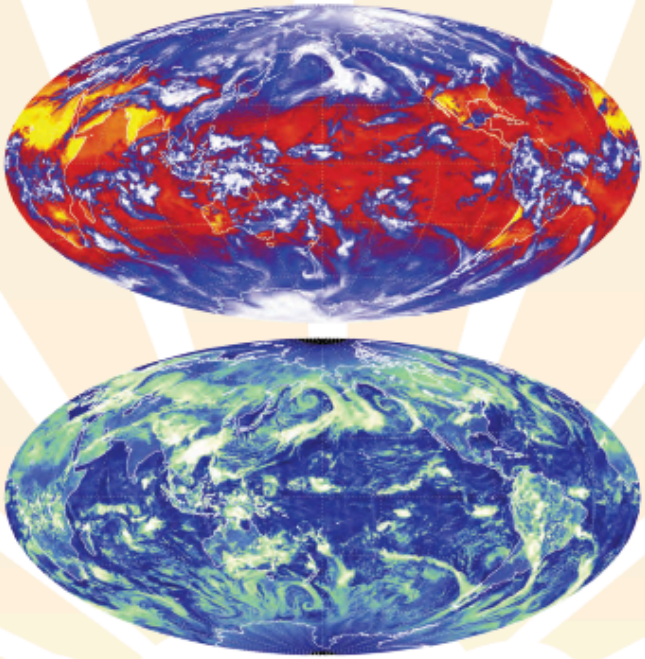
GMAO

National Aeronautics and Space Administration

NASA'S GLOBAL MODELING AND ASSIMILATION OFFICE PRESENTS

CERES

SCIENCE TEAM MEETING



September 26-28, 2017

Goddard Space Flight Center
Building 34, Room W150

Contact: Norman Loeb (norman.g.loeb@nasa.gov)

Other News

- Possible FY18 Budget Cuts (President's Budget Proposal):
    - CLARREO Pathfinder on ISS.
    - DSCOVR (Earth-viewing instruments only)
    - PACE
    - OCO-3
    - RAVAN launch November 11, 2016 on a cubesat.

20 Years of School – Happy Birthday!

CERES S'COOL PROJECT UPDATE

The Evolution and Value of a Long-Running Education Project with a Foundation in NASA Earth Science Missions

LIN H. CHAMBERS, MEGAN A. MCKEOWN, SARAH A. MCCREA, ANN M. MARTIN, TINA M. ROGERSON, AND KRISTOPHER M. BEDKA

Since 1997, S'COOL has engaged interested participants worldwide in observing clouds and comparing data from ground and satellite sources to inform validation efforts for several NASA Earth science missions.

Scientists are increasingly interested in crowd-sourced data but have concerns about its accuracy. Begun nearly 20 years ago, the Students' Cloud Observations Online (S'COOL) project, introduced to *BAMS* readers in Chambers et al. (2003), offers a unique opportunity to inform this question. S'COOL arose from a confluence of education and science needs. Teachers are able to engage students in real-world science, while NASA obtains extensive ground-based data on clouds. Here we examine the record of participation and the information gathered to assess the value of crowd-sourced Earth system data and to illuminate important considerations for scientists considering involving a wider community in their work.

Imager-based cloud retrievals (cloud/no cloud and cloud properties such as phase, optical depth, and height) are some of the foundational data sources used to determine scene characteristics within each footprint of the Clouds and the Earth's Radiant Energy System (CERES; Wielicki et al. 1996) instrument. This information is needed to analyze the radiation balance throughout the day, a precursor to understanding the Earth radiation budget (ERB) at climatological time scales (Loeb et al. 2009). Thus, it is very important to understand the accuracy of cloud retrievals as biases can influence the CERES-derived ERB. Meanwhile, students in classrooms around the world learn about clouds and the scientific process as part of the school curriculum, and many adults observe the sky individually or through hobby clubs and organizations. S'COOL connects these interests by engaging students and others in cloud observations and analysis.

AFFILIATIONS: CHAMBERS AND BEDKA—Science Directorate, NASA Langley Research Center, Hampton, Virginia; MCKEOWN—Texas A&M, College Station, Texas; MCCREA, MARTIN, AND ROGERSON—Science Systems and Applications, Inc., Hampton, Virginia
CORRESPONDING AUTHOR E-MAIL: Lin H. Chambers, lin.h.chambers@nasa.gov

The abstract for this article can be found in this issue, following the table of contents.
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In final form 27 June 2016

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